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(54) **Electronic ballast with lamp type recognition**

(57) The power supply circuit for discharge lamps (L) comprises a load circuit (15, 17, L) having at least one discharge lamp (L) and controlled switches (11, 13) with switching means (25) which control the opening and closing of the said switches to supply the load circuit (15, 17, L) with a high-frequency alternating voltage. A recognition circuit, which recognizes the type of lamp connected in the load circuit, is provided. Control means (31) which modify the switching conditions of the said switches according to the type of lamp (L) connected in the load circuit are also provided.

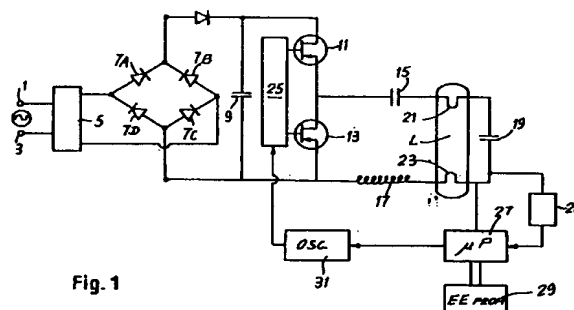


Fig. 1

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Description

The present invention relates to a power supply circuit for low-pressure discharge lamps, of the type comprising an inverter with two controlled switches which are alternately made conducting and isolating to supply a load circuit, comprising at least one lamp, with a high-frequency alternating voltage.

This type of circuit is used to supply discharge lamps of various types. Inverter power supply circuits are described, for example, in EP-A-0621743, US-A-5,426,344, EP-A-0488478, US-A-5,479,334, EP-A-0697803, US-A-5,485,060.

At present there are available on the market various types of discharge lamp, which differ from each other in their external dimensions and in their internal characteristics, particularly in the power drawn. At present, where tubular lamps are concerned, there are, for example, two classes of lamps distinguished by their external dimensions and lamps of varying power are grouped in each category. The symbol T5 is used to identify tubular discharge lamps with a small external diameter, available with power ratings of 14 and 24 watts (lamps T5FH and T5FQ). Lamps of larger diameter are identified by the symbol T8 and are available in three different versions, namely 18, 36 and 58 watts. The ballasts or inverter power supplies available at present on the market are designed for a single type of lamp, so that there is the disadvantage of having to have a large number of inverters for the various lamps. Where compact lamps are concerned, there are different shapes and connections corresponding to different power ratings.

Furthermore, the lamps in each category are externally identical, so that there is a risk of connecting a lamp with a particular power rating in a power supply circuit designed for a different power, resulting in an incorrect power supply to the lamp.

The object of the present invention is to provide an inverter power supply which overcomes the disadvantages mentioned above.

Essentially, according to the invention, a power supply circuit for discharge lamps is provided, comprising a load circuit having at least one discharge lamp and controlled switches with switching means which control the opening and closing of the said switches to supply the load circuit with a high-frequency alternating voltage. Characteristically, the power supply circuit according to the invention provides a recognition circuit which recognizes the type of lamp connected in the load circuit and control means which modify the switching conditions of the said switches according to the type of lamp connected in the load circuit.

In this way it is possible, on the one hand, to provide a single power supply, or a limited number of power supplies, for all the lamps available on the market, with considerable advantages both for the manufacturer and for the retailers and users. On the other hand, there is the elimination of the disadvantages arising from the possi-

bility of connecting an incorrect lamp to a power supply not designed to supply this type of lamp.

As will be made clear subsequently with reference to a number of possible embodiments, the inventive concept on which the invention is based may be applied both to power supplies of the self-oscillating type, with control transformers for switching the switches, and to power supplies in which the switches are controlled by means of integrated circuits. In the case of self-oscillating circuits, the power supply conditions of the lamp can be modified by varying the hysteresis of the control transformer, or the peak saturation voltage across the terminals of one of the secondary windings of the control transformer, or by providing a cyclic switch-off, for a time which can be pre-set, of the self-oscillating circuit.

In the case of switches controlled by an integrated circuit, the power supply conditions of the lamp may be modified, for example, by varying the switching frequency, or the duty cycle of the switches, or again by providing for the temporary and cyclic switch-off of the switches for time intervals which can be modified according to the type of lamp connected in the load circuit.

Various possible methods of varying the power supply conditions of the lamp will be described in greater detail in the following text.

Both in the case of self-oscillating circuits and in the case of circuits in which the switching of the switches is controlled by a suitable integrated circuit, the circuit for recognizing the type of lamp connected in the load circuit is preferably based on the recognition of the resistance of the filaments of the lamp. This recognition may take place in the cold state, for those lamps whose filaments have sufficiently different resistances when cold, or in the hot state, for those lamps whose filament resistances are identical in the cold state, but varies with the temperature and therefore becomes different in power supply conditions.

Other methods of recognition of the lamp, for example by identification of the voltage at its terminals, are not excluded. Indeed, the discharge lamps available at present on the market differ not only in the resistance of the filaments, but also in the potential difference developed between the filaments. At present, this potential difference depends on the ambient temperature. It is therefore useful for the recognition circuit to be capable of recognizing the lamp in different conditions of ambient temperature, and for this purpose a temperature sensor may be provided, associated, for example, with a microprocessor connected in the recognition circuit.

Further advantageous characteristics and embodiments of the power supply circuit according to the invention are indicated in the attached claims and/or described in the following text with reference to the attached drawings.

The invention will be more clearly understood from the description and the attached drawings, which show practical non-restrictive embodiments of the invention.

More particularly,

Fig. 1 is a diagram of a power supply according to the invention with an oscillator associated with the control circuit of the switches of the inverter;

Fig. 2 is a diagram of the oscillator shown in Fig. 1; Figs. 3, 4 and 5 are three different block diagrams relating to the method of recognition of the lamp connected in the power supply circuit;

Figs. 6, 7 and 8 show different waveforms of the supply voltage of the load circuit;

Fig. 9 is a diagram similar to the diagram in Fig. 1, in a simplified version;

Figs. 10 and 11 are two diagrams of power supplies according to the invention, of the self-oscillating type;

Fig. 12 is a diagram of a power supply with recognition of the lamp by measurement of the voltage between the electrodes; and

Fig. 13 is a diagram of the voltage across the terminals of the lamp as a function of the current for various temperatures.

Fig. 1 shows schematically a power supply circuit for a discharge lamp L. The numbers 1 and 3 indicate the connections to an alternating current power supply network, for example the normal electrical mains. The number 5 indicates a filter interposed between the power supply network and a rectifier bridge formed by four diodes 7A-7D. The number 9 indicates a smoothing capacitor and 11 and 13 indicate two controlled switches, which are alternately made conducting and isolating to supply an oscillating load circuit comprising, in addition to the lamp L, an inductor 17 in series with a capacitor 19 in parallel with the lamp L. The number 15 indicates a capacitor in series with the lamp L. The opening and closing of the switches 11, 13 are controlled by an integrated control circuit indicated in a general way by 25, of a type known in itself.

The load circuit comprising the lamp L is associated with a microprocessor 27, with an EEPROM memory 29, which controls an oscillator 31 in the way described below.

The lamps of class T8 have filaments which have resistances in the hot and cold states which vary from lamp to lamp as a function of the power, but the difference between the hot resistance of the various lamps is more marked than the difference between the filament resistances of the lamps in the cold state, the ratio between the hot and cold resistances remaining approximately constant at 4.5-5.5 for the various types of lamp. It is therefore useful to measure the resistance in the hot state to obtain greater resolution.

At the operating temperature, to which the filaments are raised when the discharge lamp is in the normal operating conditions, supplied with the correct current corresponding to the rated power of the lamp, each lamp of class T8 has different filament temperatures

and consequently different filament resistances which are greater than the values of resistance in the cold state, the filament resistances having a positive temperature coefficient.

In this embodiment, the circuit according to the invention is based on this circumstance, to recognize the type of lamp connected in the load circuit and consequently to modify the power supply conditions of the circuit.

In practice, the microprocessor 27 is programmed to recognize the lamp among a set of possible lamps which differ in the power drawn. It is programmed in such a way that when the power supply circuit is switched on the lamp L is supplied with the minimum current, in other words that corresponding to the lamp with the minimum power available on the market. At present, in the case of lamps of class T8, the minimum available power is 18 watts.

The lamp is supplied at the minimum current until the filaments 21, 23 have heated up and have reached a substantially constant temperature. This temperature corresponds to a certain resistance which can be measured easily, since the supply current is known. If the lamp is supplied with the correct value of current, in other words with the value corresponding to the rated power of the lamp, the filaments have reached the temperature and consequently the (known) resistance of operation in normal operating conditions. The microprocessor recognizes this situation and maintains the power supply conditions without modification.

If the lamp has a power rating different from that corresponding to the supply current, the lamp will be under-powered, so that the temperature reached by the filaments (and therefore their resistance) will be lower than the nominal operating temperature. The microprocessor 27 recognizes this under-powering situation and therefore emits a signal which increases the supply current to the lamp to the value corresponding to the supply current for the lamp with a higher power rating. At this point the checking cycle recommences.

The check algorithm described in summary form is shown in the block diagram in Fig. 3, where the letter N indicates a counter which can have a value from 1 to a number corresponding to the maximum number of lamps recognizable by the circuit, a progressive value of lamp power corresponding to each progressive number. For example, in the case of lamps of class T8, $N = 1, 2$ or 3 for power ratings of 18 W, 36 W and 54 W respectively. The letter I indicates the supply current of the load circuit, I_N indicates the nominal supply current for the N-th lamp of the set of lamps recognizable by the system, R_{FIL} indicates the resistance of the filament of the lamp with a supply current I_N applied, and R_N indicates the resistance which the filament of the N-th lamp of the set has when it is supplied at the correct current value.

The checking cycle is reiterated with the counter N incremented on each occasion until the microprocessor 27 finds that the resistance R_{FIL} of the filament of the

connected lamp is equal to or greater than the nominal value R_N . The power supply conditions of the lamp are modified by means of the oscillator 31 in the way which will be illustrated subsequently.

In the illustrated example, the cycle for checking the type of lamp connected in the load circuit is repeated with every switch-on of the lamp. However, this is not necessary, since when the lamp has been connected, the type of lamp has been recognized and the correct power supply condition has been set, this can be maintained until the lamp is replaced. It is therefore possible to program the microprocessor 27 so that it carries out the check once in every predetermined number of switch-ons, as shown in Fig. 4, where the letter A indicates a counter which is incremented with every switch-on and A_x indicates the number of switch-ons between one check and the next.

Conversely, Fig. 5 shows the check algorithm in the case in which the check is made only at a switch-on following a replacement of the lamp. For this purpose, it is necessary to provide means which inform the microprocessor that the removal and replacement of the lamp has taken place. For this purpose it is possible to provide, for example, a sensor 28, whose output has a high value at the first switch-on of the lamp and maintains this value until the lamp is removed, in case of failure for example. On such an occasion, the output of the sensor 28 has a value of zero, and remains at this value until the microprocessor 27 has carried out the new recognition of the lamp L after its replacement. The replacement must take place with the ballast switched on so that the sensor 28 can detect that the replacement has taken place.

Fig. 2 is a diagram of the oscillator 31. It has a capacitor 41 which is charged by a current I_0 from a current source 43. The voltage across the capacitor 41 is applied to the positive input of a comparator 45 to whose negative input a threshold voltage V_s is applied. The output 47 of the comparator 45 is low (0) until the voltage across the capacitor 41 is lower than the threshold voltage V_s , while it changes to the high value (1) when the voltage across the terminals of the capacitor 41 is equal to the threshold voltage V_s . When the output of the comparator 45 switches from 0 to 1, the switch 49 is closed to discharge the capacitor 41 and then reopens to recommence the capacitor charging cycle. The discharge time of the capacitor 41 is constant, while the charging time varies with the variation of the current I_0 supplied by the current generator 43. It is therefore possible to vary the duty cycle of the signal on the output 47 of the comparator by varying the current I_0 .

If the signal on the output 47 is used to control the switches 11, 13 of the inverter directly, the supply current to the lamp L can be modified by varying the time T_{off} (see Fig. 2) of the signal at the output of the oscillator 31 and consequently the duty cycle of the switching signal of the switches 11, 13. Fig. 6 shows the waveform of the switching signal for two different operating condi-

tions. As shown in Fig. 6, the conduction time T_{on} is kept constant and the isolation time T_{off} of the controlled switches 11, 13 is varied.

Alternatively, it is possible to modify the power supply conditions of the lamp L by varying the frequency of the switching signal. This may be done by sending the signal at the output of the comparator 45 to a divider 49 whose output is represented by a symmetrical square wave signal, at a frequency which is a function of the charging time of the capacitor 41, and which is used as a switching signal for the switches 11, 13. Fig. 7 shows the waveform of the switching signal in two different power supply conditions.

Instead of varying the current I_0 to modify the charging time of the capacitor 41, it is also possible to make the oscillator 31 operate at constant frequency, for example of the order of tens of kHz, and to have this stopped for intervals of time which can be varied and set. This may be done, for example, by providing a control switch 51 operated by the microprocessor 27, with a fixed open time and a variable closed time. When the switch 51 is open, the oscillator generates at the output a high-frequency driving signal for the controllable switches 11, 13 of the inverter, so that the lamp L is supplied at a specific frequency. When the switch 51 is closed, the output signal of the oscillator 31 is low, and the controlled switches 11, 13 are turned off, so that the power supply to the lamp L is interrupted.

By increasing or reducing the closed time of the control switch 51, the power supply conditions of the lamp L are varied according to the type of lamp, while the switching frequency of the inverter is kept constant. Fig. 8 shows the variation of the current in the load circuit in two different power supply conditions. In the intervals T_{on} , the lamp L is supplied at a specific frequency, while in the intervals T_{off} the lamp is not supplied. The duration of the time T_{off} varies according to the type of lamp L connected in the load circuit.

Some types of lamp, and in particular lamps belonging to the T5 class, have filaments which have different resistances in the cold state. In this case, it is not necessary to heat the filaments to determine the type of lamp connected in the load circuit; it is sufficient to measure the resistance of the filaments of the lamp in the cold state. It is therefore possible to provide a simple threshold circuit and a current generator associated with one of the filaments of the lamp L, as shown in Fig. 9, where the number 61 indicates the threshold circuit and the number 63 indicates the current generator. The signal at the output of the threshold circuit 61 is sent to the oscillator 31 which modifies the behaviour of the checking circuit 25 in the way described previously. If it is necessary to recognize more than two lamps, which are all different from each other in respect of the resistance of the filaments in the cold state, it is sufficient to provide a number of threshold circuits in series or in parallel.

In the preceding text, reference has been made to

an inverter with an integrated circuit for controlling the switching of the controlled switches 11, 13. However, it is possible to provide a universal inverter which also has a configuration of the self-oscillating type. This possibility is illustrated with reference to Fig. 10, in which identical or equivalent parts are indicated by the same reference numbers as those used in Fig. 1. In this embodiment, the load circuit comprises a winding 71 which forms the primary winding of a saturable control transformer, whose two secondary windings 73, 75 are connected to the bases of the transistors 11, 13. The operation of the inverter in this configuration is known and will not be described in greater detail.

In this case, the power supply condition of the lamp L can be modified by varying the conditions of saturation of the control transformer 71, 73, 75. For this purpose, an auxiliary winding 77 is provided, associated with a current generator 79. The current I_1 supplied by the current generator 79 modifies the saturation time of the control transformer 71, 73, 75 of the inverter, and consequently modifies the switching frequency of the switches 11, 13. As in the case described previously, the microprocessor 27 determines, by the method illustrated in Figs. 3, 4 or 5, the type of lamp L connected in the load circuit, and consequently sets the current I_1 which the current generator 79 must supply to obtain the correct power supply for the lamp.

Alternatively, it is possible to provide, in place of the current generator 79, a switch 81 which is cyclically closed for time intervals which can be determined by the microprocessor 27. When the switch 81 is closed, the self-oscillating circuit is switched off and the supply to the lamp L is interrupted. When the switch 81 is opened, the self-oscillating circuit is again switched on by a starting DIAC 83, and the lamp is supplied at a fixed frequency for the time interval in which the switch 81 remains open. The current to the lamp has the variation shown in Fig. 8 and the power supply conditions of the lamp are modified according to the type of lamp by varying the closed time T_{off} of the switch 81.

Fig. 11 shows a different embodiment of the self-oscillating inverter, in which the power supply condition of the lamp L is modified by varying the base voltage of the switch 16. For this purpose, one of the terminals of the secondary winding 75 is connected to a transistor 76, whose base is connected to the microprocessor 27, which thus controls the voltage in the winding. Since the switch-on time of the switches 11, 13 is linked to the voltage across the terminals of the secondary windings of the control transformer by the relation:

$$T_{on} = (\phi_{sat} N)/V$$

where ϕ_{sat} is the magnetic flux of saturation of the control transformer and N is the number of turns of the winding, it is possible, by varying V, to vary T_{on} and consequently the power supply conditions of the lamp L.

In the case of self-oscillating inverters also, the rec-

ognition of the lamp connected in the load circuit, and consequently the determination of the power supply conditions of the lamp, may take place for certain types of lamp with a threshold circuit as described with reference to Fig. 9.

Discharge lamps have a potential difference between the electrodes 21, 23 which is a function of the supply current I and of the type of lamp. It is therefore theoretically also possible to construct a circuit capable of recognizing the type of lamp connected in the load circuit from the voltage across the terminals of the lamp, instead of from the resistance of the filament.

Fig. 12 is a diagram of a power supply similar to that shown in Fig. 1, in which identical or corresponding parts are indicated by the same reference numbers, and in which the microprocessor 27 is connected to the load circuit in such a way as to measure the voltage between the electrodes of the lamp. This voltage varies, as a function of the current flowing in the electrodes, as shown in the diagram in Fig. 13, where the current is shown on the horizontal axis and the voltage across the terminals of the lamp is shown on the vertical axis. The characteristic $V(I)$ varies as a function of the ambient temperature T. It is therefore necessary in this case for the microprocessor 27 to be associated with an ambient temperature sensor St . When the ambient temperature has been identified, the microprocessor 27 is able to select the reference curve $V(I)$. A plurality of such curves for different values $T_1, T_2, T_3 \dots$ may be stored, for example, in tabular form in the EPROM 29.

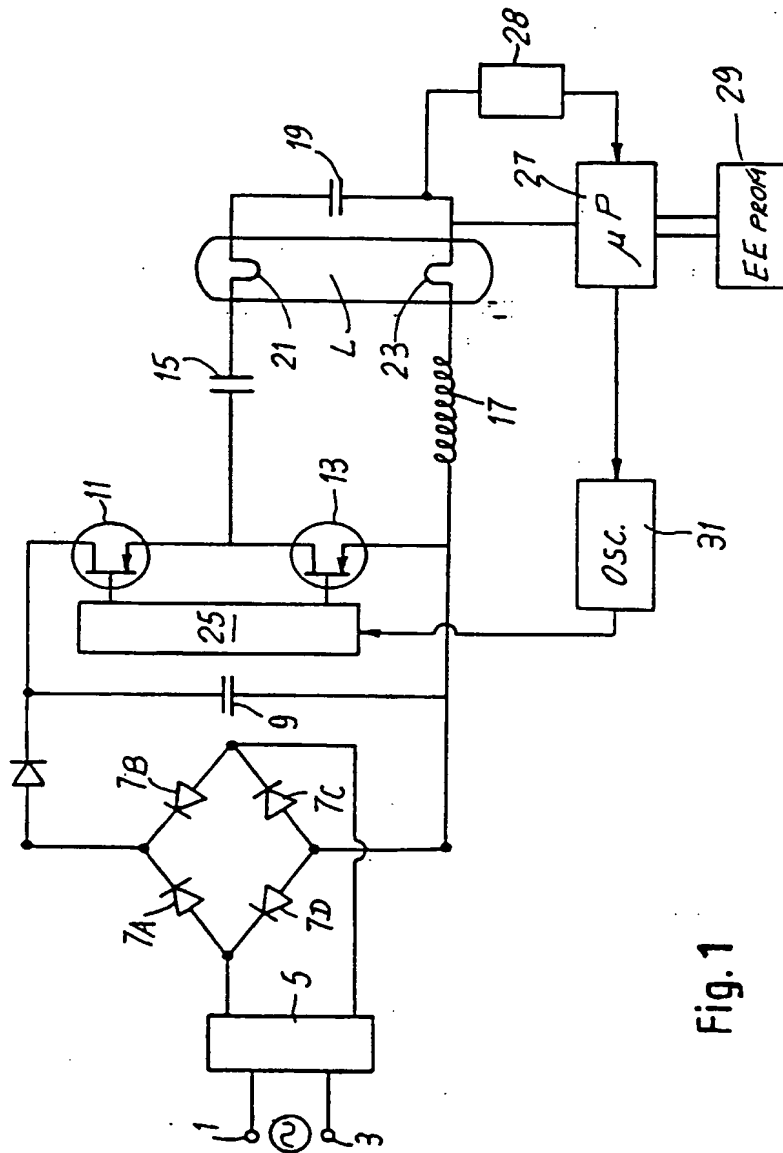
The algorithm for the recognition of the connected lamp may be the same as that described with reference to the diagrams in Figs. 3, 4 or 5, with the difference that for each value of current I_N a voltage V_N is measured instead of a filament resistance.

It is to be understood that the drawing shows only a example provided solely as a practical demonstration of the invention, and that the said invention may vary in its forms and dispositions without departure from the scope of the guiding concept of the invention. Any presence of reference numbers in the attached claims has the purpose of facilitating the reading of the claims with reference to the description and to the drawing, and does not limit the scope of the protection represented by the claims.

Claims

1. A power supply circuit for discharge lamps (L), comprising a load circuit (15, 17, L) having at least one discharge lamp (L) and controlled switches (11, 13) with switching means (25; 71, 73, 75) which control the opening and closing of the said switches to supply the load circuit (15, 17, L) with a high-frequency alternating voltage, characterized by a recognition circuit which recognizes the type of lamp connected in the load circuit and control means (31; 79; 81) which modify the switching conditions of the said

- switches according to the type of lamp (L) connected in the load circuit.
2. Circuit according to Claim 1, characterized in that the said recognition circuit determines the resistance of at least one filament (21; 23) of the lamp (L) connected in the load circuit. 5
 3. Circuit according to Claim 2, characterized in that the said recognition circuit determines the resistance of the filament of the lamp in the hot state. 10
 4. Circuit according to Claim 1, characterized in that the said recognition circuit determines the voltage across the terminals of the lamp (L). 15
 5. Circuit according to one or more of the preceding claims, characterized in that the said recognition circuit comprises a microprocessor (27). 20
 6. Circuit according to Claim 5, characterized in that the said microprocessor is programmed to supply the said lamp (L) with a current (I) equal to the supply current (I_1) of the lamp (L) with the lowest power rating of a group of lamps recognizable by the said recognition circuit; to check whether the lamp is correctly supplied with the said supply current (I_1); and to increment the supply current (I) to successive values ($I_2 \dots I_N$) corresponding to the values of the supply current of the lamps with increasing power ratings of the said group of lamps, until the condition of correct supply is reached. 25 30
 7. Circuit according to Claim 6, characterized in that the said microprocessor is programmed to determine, for each supply current (I_N), the resistance (R_{FIL}) of at least one filament of the lamp (L) and to compare the said resistance (R_{FIL}) with the temperature corresponding to the condition of correct supply of the lamp. 35 40
 8. Circuit according to Claim 2, characterized in that the said recognition circuit determines the resistance of the lamp filament in the cold state. 45
 9. Circuit according to Claim 8, characterized in that the said recognition circuit comprises a threshold circuit (61) and a current source (63). 50
 10. Circuit according to one or more of the preceding claims, characterized in that the said recognition circuit comprises means (28) to check whether the lamp has been removed and replaced. 55
 11. Circuit according to Claim 10, characterized in that the said recognition circuit carries out the recognition of the lamp when the lamp is switched on only when the said lamp has been replaced.
 12. Circuit according to one or more of the preceding claims, characterized in that the said control means comprise an oscillator (31) whose output signal controls the said means (25) of switching the said switches (11, 31), and in that the recognition circuit modifies the output of the said oscillator according to the type of lamp connected in the load circuit.
 13. Circuit according to Claim 12, characterized in that the oscillation frequency of the said oscillator is modified by the recognition circuit.
 14. Circuit according to Claim 12, characterized in that the duty cycle of the output signal of the said oscillator (31) is modified by the recognition circuit.
 15. Circuit according to Claim 12, characterized in that the output of the said oscillator (31) is switched off for an off time interval (T_{off}) whose duration is set by the said recognition circuit.
 16. Circuit according to one or more of Claims 1 to 11, characterized in that the said switching means comprise a control transformer (71, 73, 75) with an auxiliary winding (77), and in that the said recognition circuit modifies the conditions of the current flow in the said auxiliary winding (77) according to the type of lamp connected in the load circuit.
 17. Circuit according to Claim 16, characterized in that the said auxiliary winding (77) is connected to a current source (79), the current supplied by this source to the said auxiliary winding (77) being set by the said recognition circuit according to the type of lamp connected in the load circuit.
 18. Circuit according to Claim 16, characterized in that the said auxiliary winding (77) is connectable to earth through a switch (81) which is closed cyclically to interrupt, for a time interval set by the said recognition circuit according to the type of lamp connected in the load circuit, the switching of the said switches (11, 13) and to make the said switches simultaneously isolating.
 19. Circuit according to one or more of Claims 1 to 11, characterized in that the said switching means comprise a control transformer (71, 73, 75) with a primary winding (71) associated with the load circuit and corresponding secondary windings associated with the said controlled switches (11, 13), the peak voltage (V) of one of the said secondary windings being set in an adjustable way by the said recognition circuit according to the type of lamp connected in the load circuit.



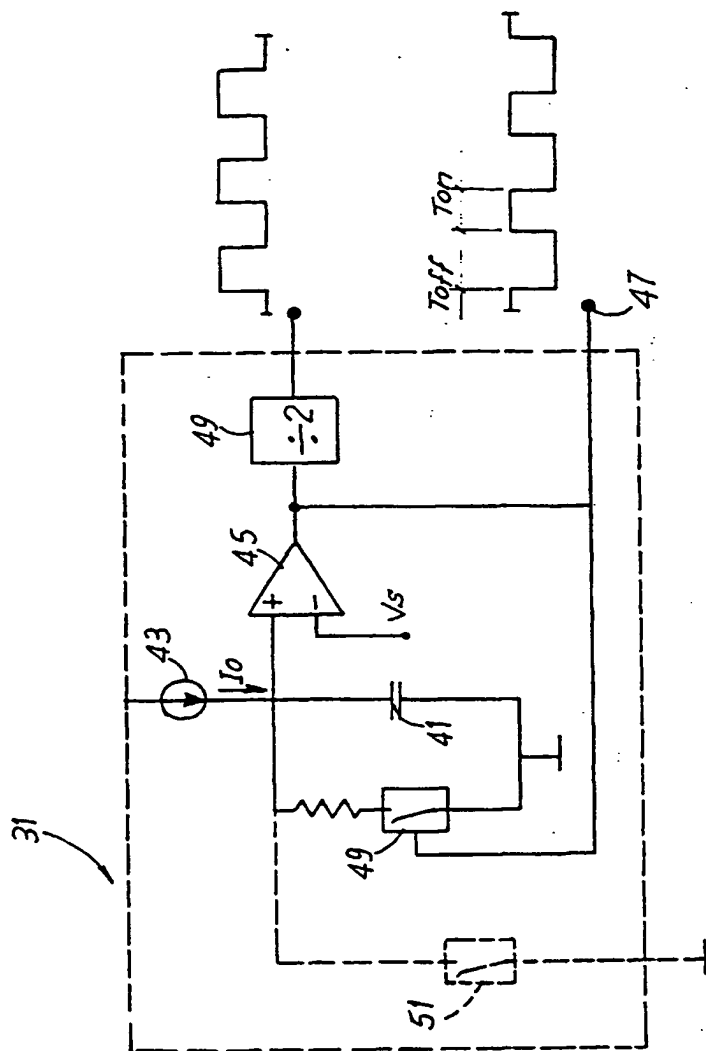


Fig. 2

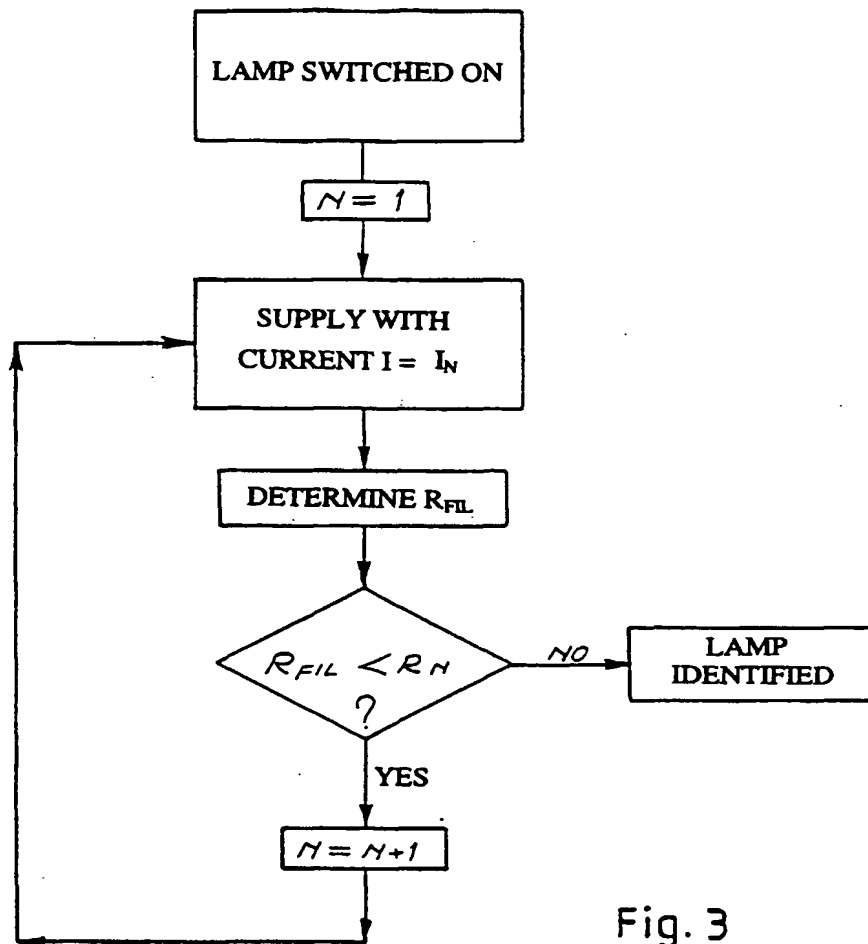


Fig. 3

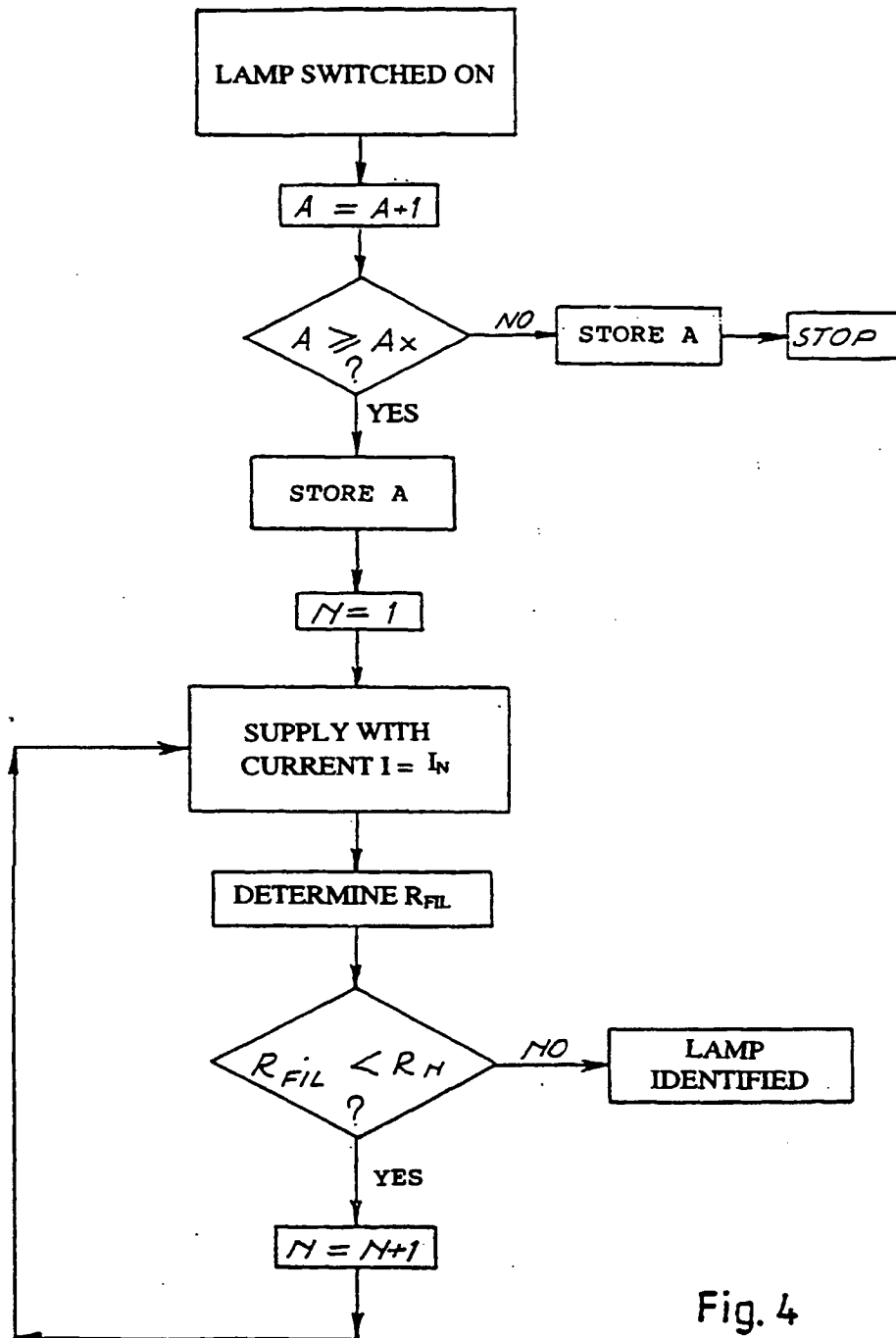


Fig. 4

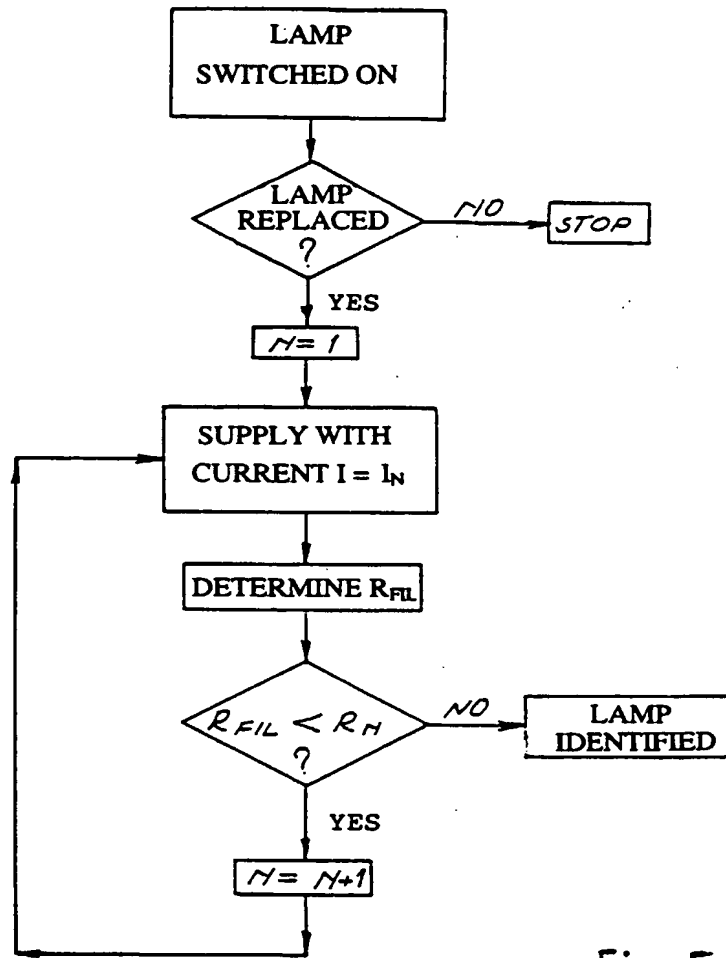


Fig. 5

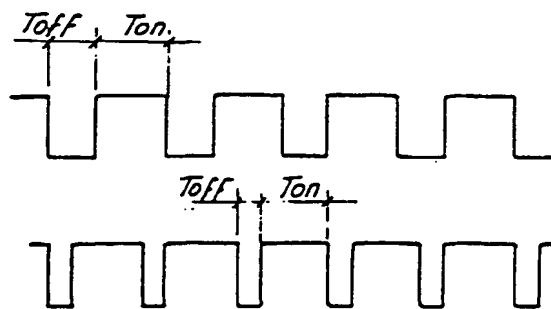


Fig. 6

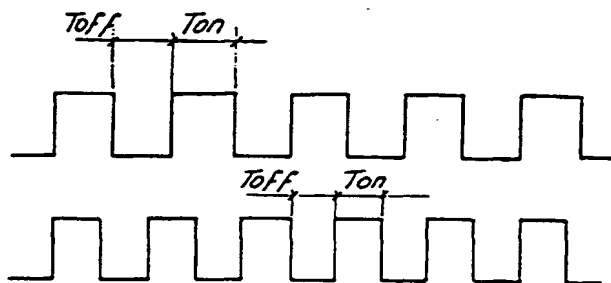


Fig. 7

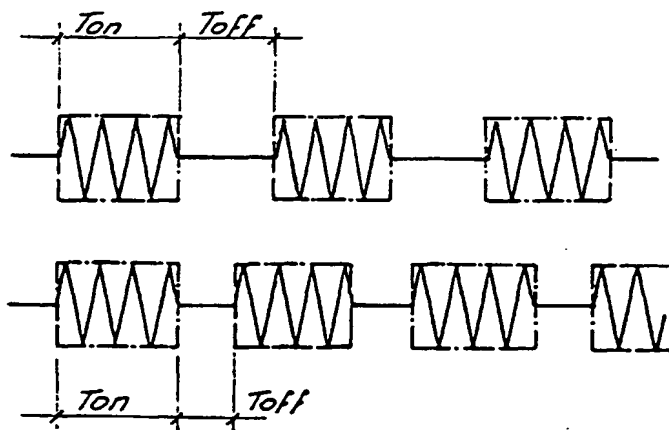


Fig. 8

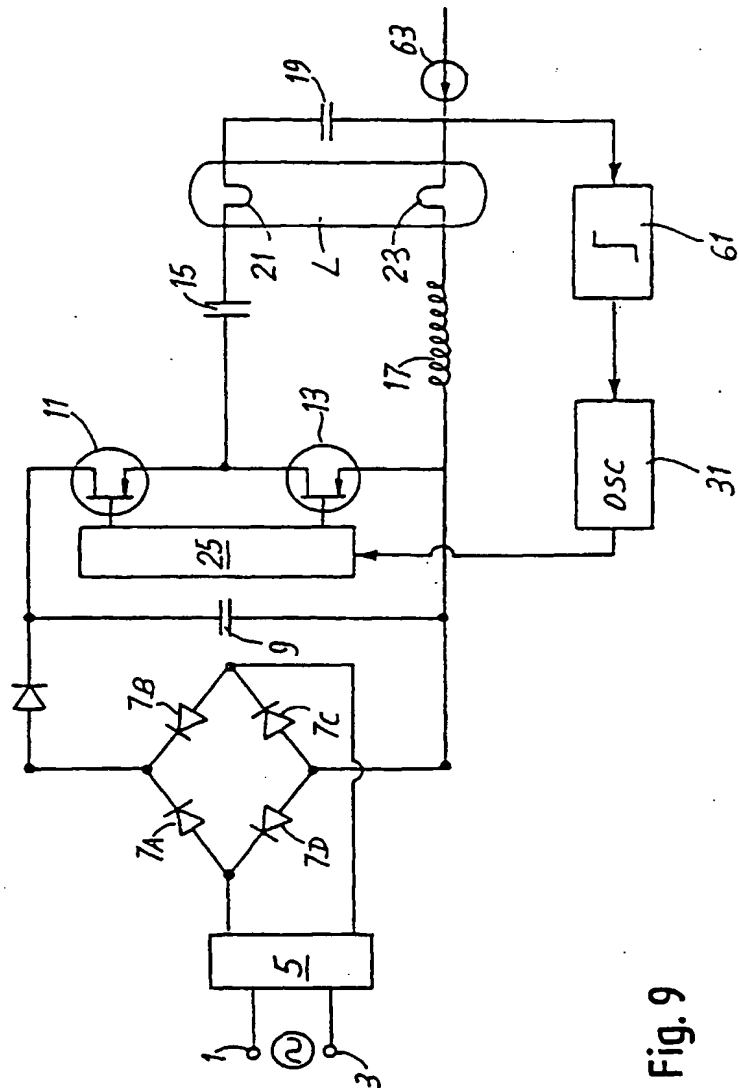
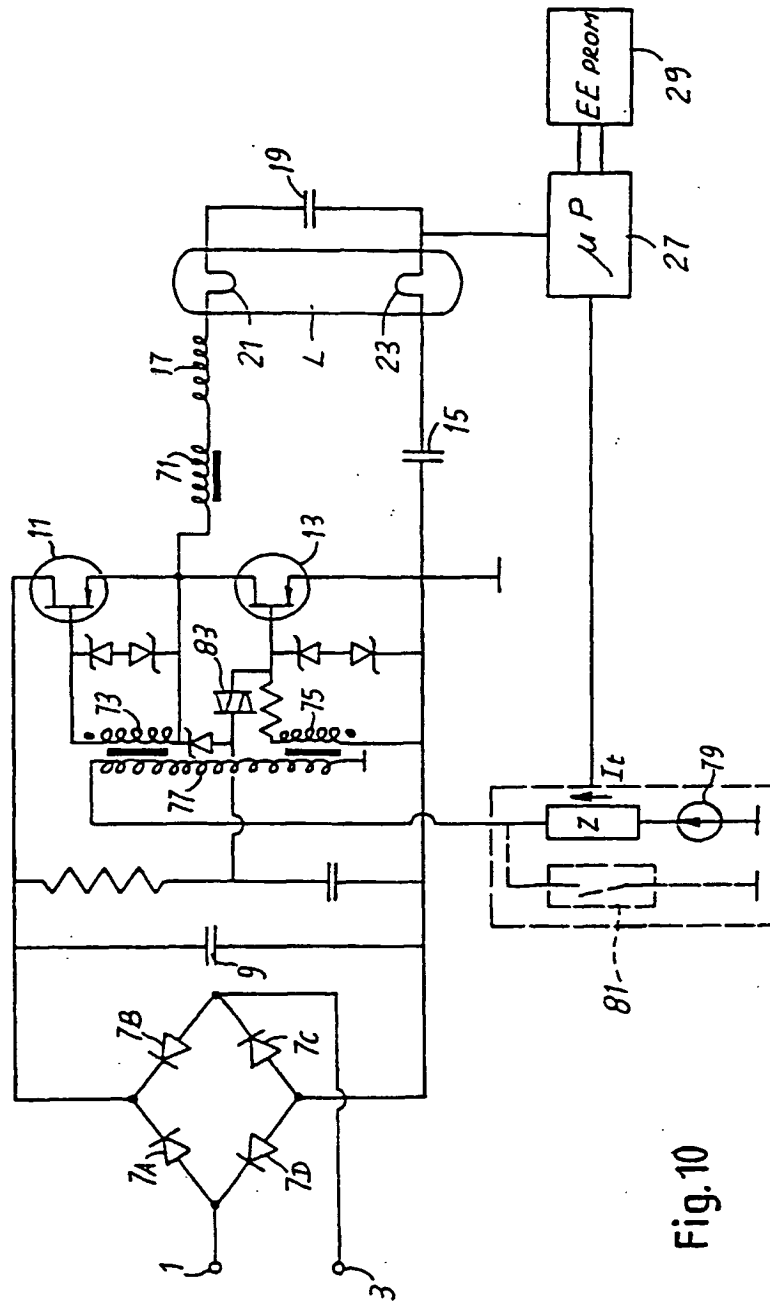


Fig. 9



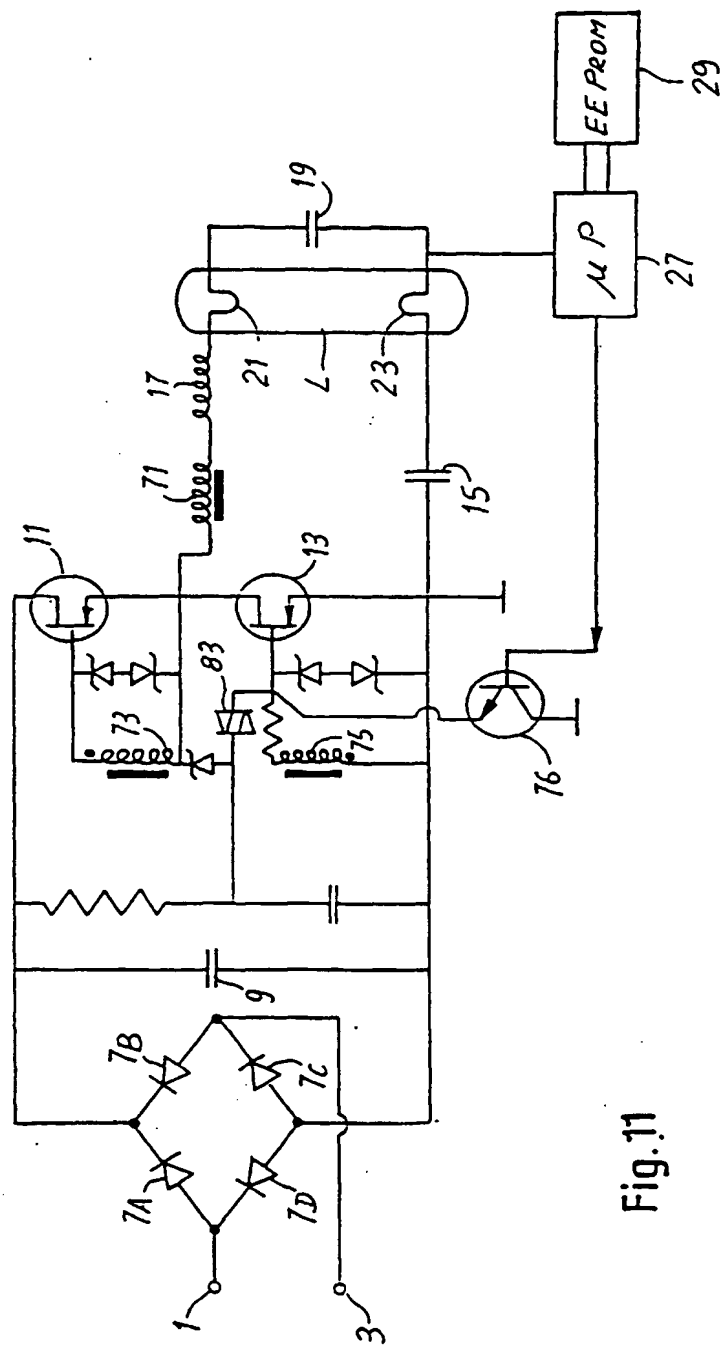


Fig.11

Fig. 12

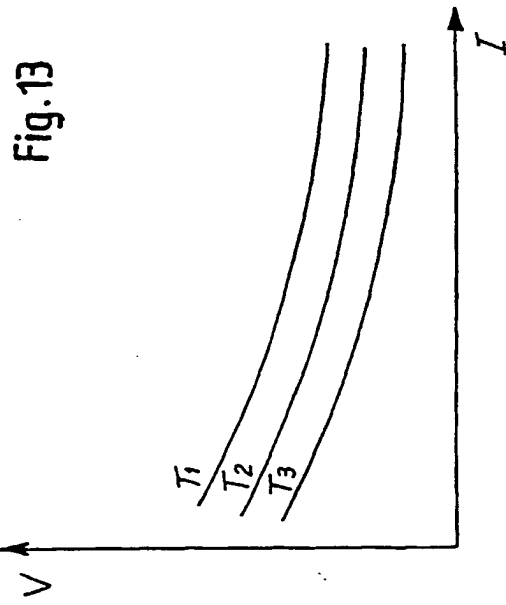
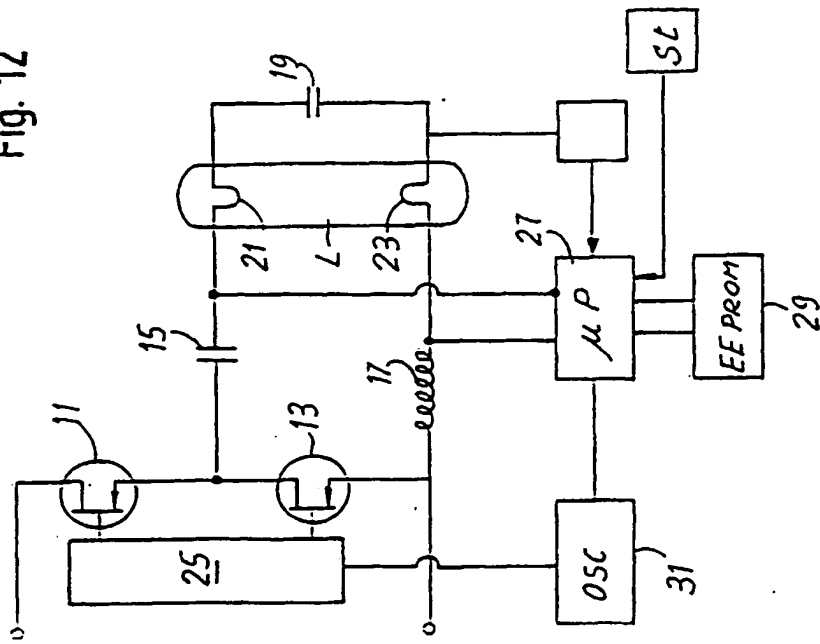


Fig. 13



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 83 0331

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	EP 0 759 686 A (PATRA PATENT TREUHAND) * page 2, line 35 - page 2, line 58; figures 1,4 *	1,5,6 2-4	H05B41/00 H05B41/29
X	EP 0 413 991 A (TOSHIBA LIGHTING & TECHNOLOGY) * abstract; figures 1,3,4,6 *	1,5,12, 13	
Y A	EP 0 594 880 A (KNOBEL LICHTTECH) * column 4, line 51 - column 4, line 56; figures 3,4 *	2-4 7,8	
A	EP 0 677 981 A (KNOBEL LICHTTECH) * column 2, line 48 - column 3, line 14; figure 1 *	10	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H05B
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 3 November 1997	Examiner Speiser, P
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